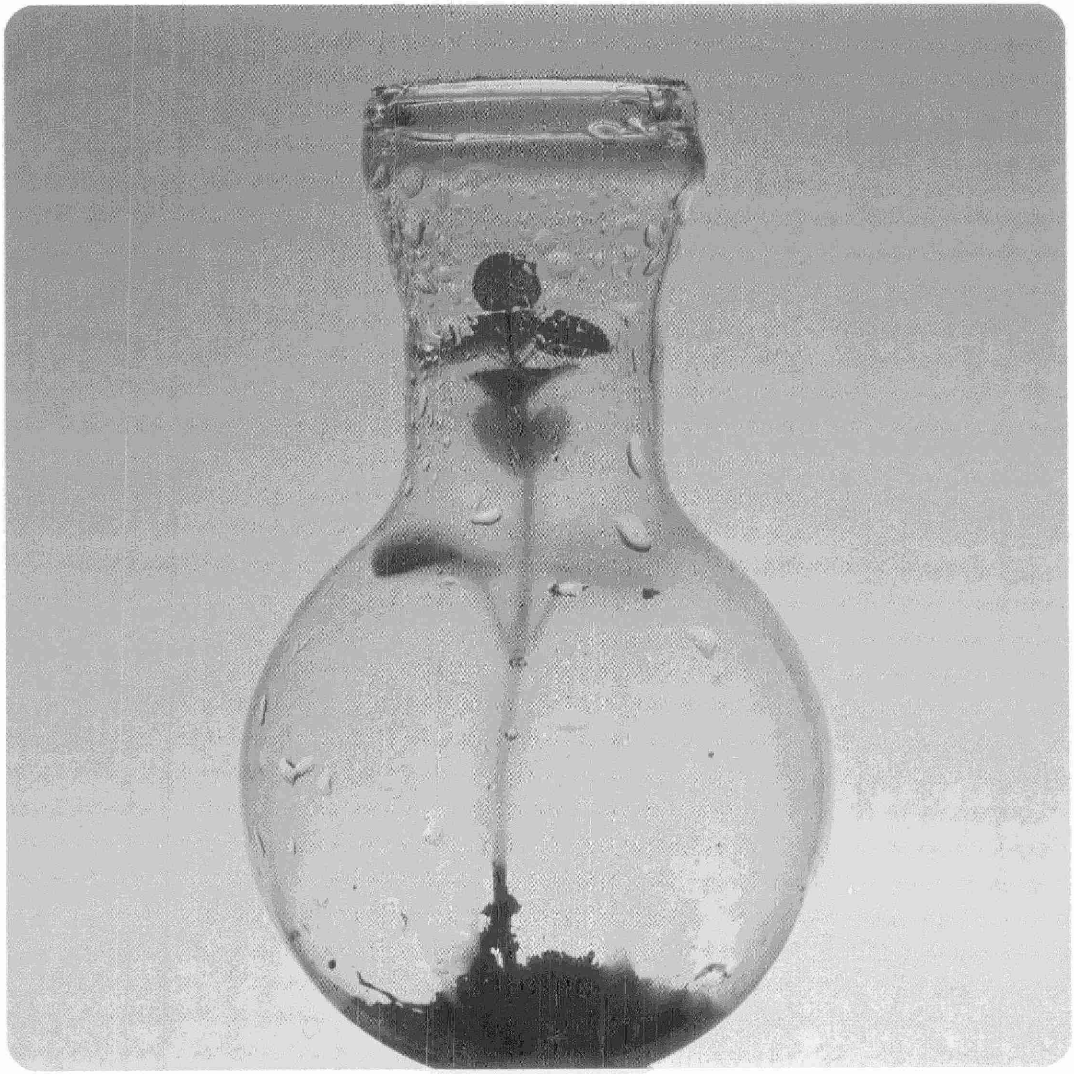
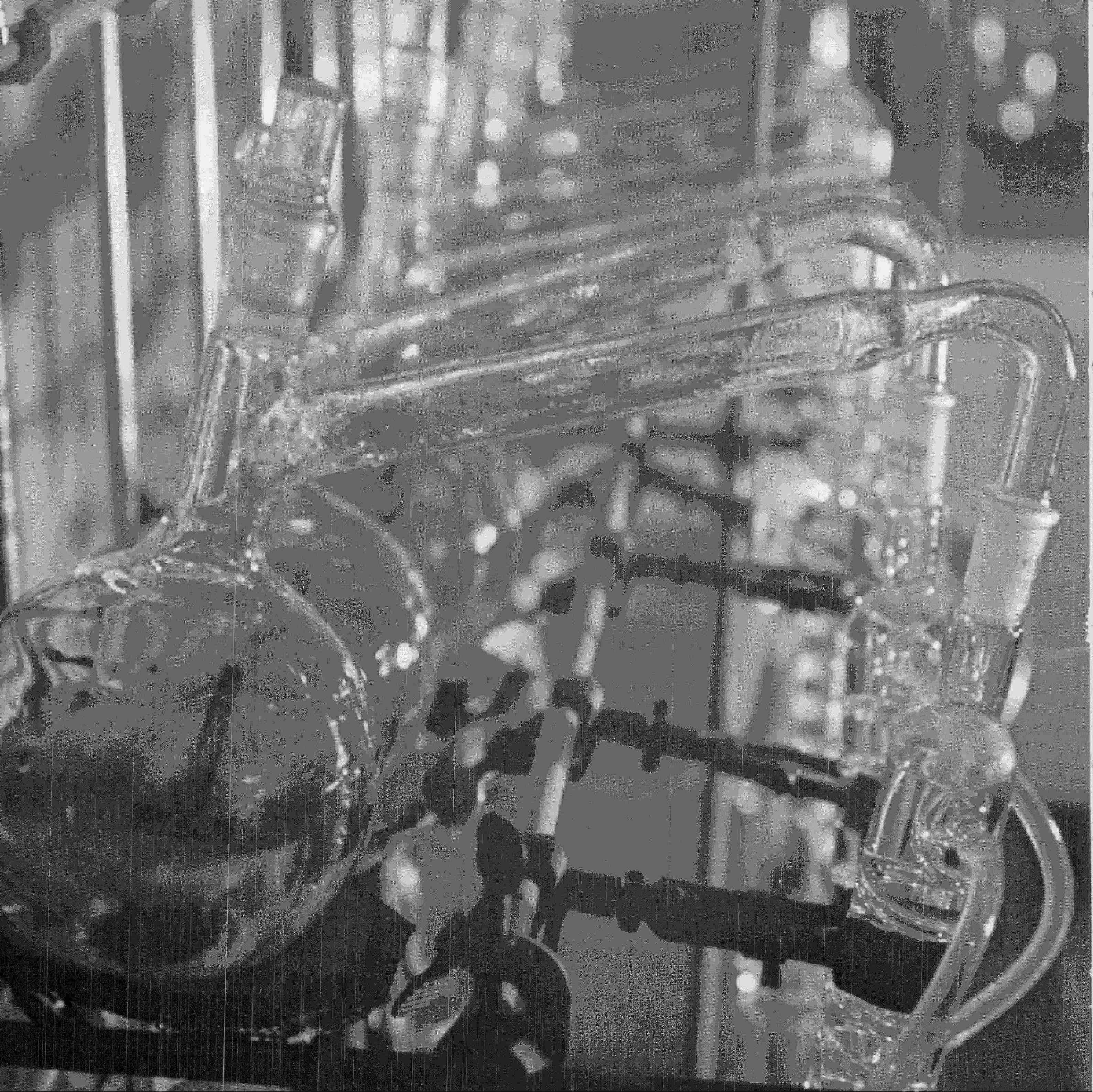
Analyzing Our Environment

Ontario

Ministry of the Environment

Hon. William G. Newman, Minister
Everett Biggs, Deputy Minister





Analyzing Our Environment

The Work of the
Laboratory Services Branch
of the
Ontario Ministry of the Environment

Towards Analysis

The environment is a complex, interwoven system, and its protection by an agency such as the Ontario Ministry of the Environment demands a wide range of functions—pollution monitoring and detection, the setting of standards for contaminant levels, development of pollution control programs, research and laboratory analysis.

With its considerable human, physical and technical resources, Environment Ontario is able to undertake the simultaneous examination of virtually every aspect of a given environmental problem.

General public awareness of the Ministry's activities varies considerably. Some are fairly well known—for example, certain abatement programs and the air pollution index system operating in several Ontario cities.

For every visible activity, however, there is a vast amount of behind-the-scenes work underway which is essential to the success of the Ministry's programs and to the well-being of the people of Ontario.

A vital activity in this category is the work of laboratory analysis.

help a fish attend the
school of its choice

A Matter of Life

The work of the laboratory, with its white-coated staff surrounded by glass and machinery, may seem routine and uneventful to some. Yet it is this complex apparatus and the people who use it, which together constitute an early warning system which serves to protect the quality of life for the people of Ontario. Within their test tubes and under their microscopes, many important environmental conditions come to light.

A water sample scooped from a bathing area contains an unsafe level of bacteria.

A sample of dust gathered from a downtown backyard holds a dangerous amount of lead.

A fish caught in a recreational lake yields a high concentration of mercury.

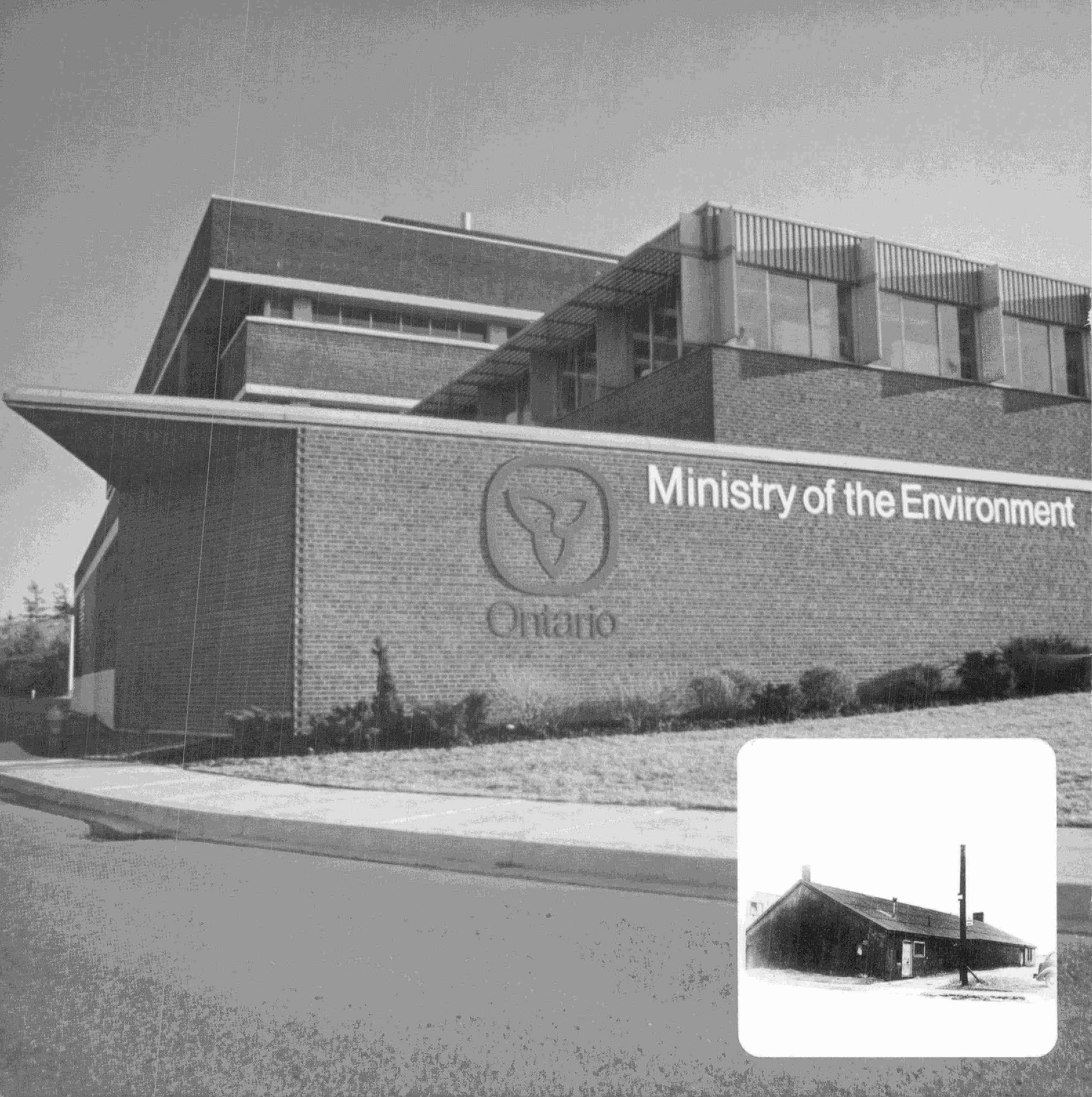
A plant picked from a suburban garden is dead from a fatal dose of sulphur dioxide.

Such are the problems revealed by the work of the Laboratory Services Branch of the Ontario Ministry of the Environment.

Much of the branch's work is done on a routine basis, some of it as a result of special Ministry investigations or in response to citizen complaints. In total, more than a million laboratory tests are conducted every year on samples of air, soil and water as well as on animal, vegetable and mineral specimens gathered from all over the province.

The purpose of all this effort? To maintain a constant watch on the environmental quality of Ontario.

One microscope's view of bacteria.


Ministry of the Environment
Ontario

Co-operation at All Levels

The vital task of environmental quality assessement is a many-sided venture involving close co-operation between the Laboratory Services Branch and various other branches of the Ministry.

In addition to providing analytical services and scientific expertise, the branch participates in the planning and data interpretation connected with specific programs. At the same time, the branch strives to refine existing analytical methods and to develop procedures for measuring and assessing new environmental pollutants.

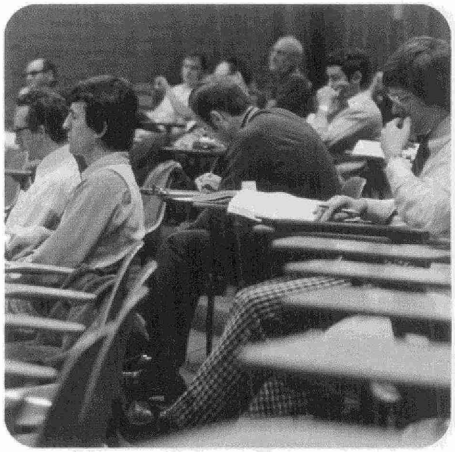
Programs within the Ministry cover a wide spectrum of activity. Examples include a study of the distribution of toxic mercury salts in aquatic systems; a study of acid lake waters in the Sudbury area; and surveys of the air of Ontario cities to determine levels of various hydrocarbons.

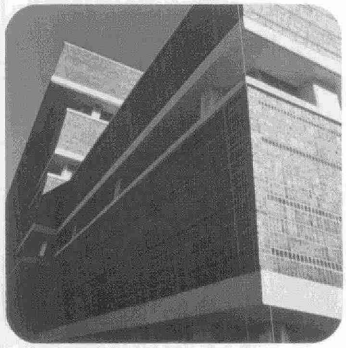
The laboratory staff also work on joint projects with other Ontario ministries. In addition, they participate in transboundary pollution studies at the national level with departments of the federal government and internationally with the U.S. Environmental Protection Agency and the International Joint Commission.

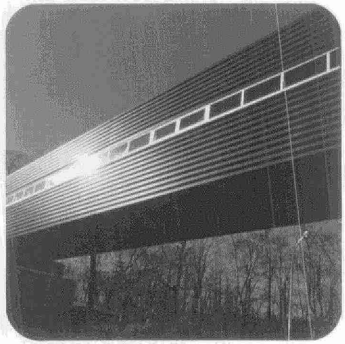
On-site monitoring for contaminants is carried out by several groups in the Ministry. At one time, every environmental sample gathered out-of-doors had to be brought to a lab for analysis. Today, after numerous technological advances, many parameters are monitored on the spot by continuous measuring instruments placed on rooftops or towers or in lakes and streams.

Among the air parameters assessed in this manner are sulphur dioxide, carbon monoxide, oxides of nitrogen and suspended dust particles; water parameters include acidity, alkalinity and conductivity. Many air monitors are connected to telemetering systems by which the data being generated are fed in a steady stream to a central computer in Toronto for quick interpretation and remedial action if necessary.

Direct monitoring has had a tremendous impact upon the business of environment-watching. One major result has been the opportunity to redirect valuable laboratory time from routine testing to more intensive investigations into the composition and behaviour of an ever-increasing number of pollutants.







Among many views of the existing central laboratory complex is a reminder (inset left) of its 1950's predecessor.

At Home on the 401

The range and scope of the work of the Laboratory Services Branch is reflected by the facilities required to house its operations.

Main headquarters is the Laboratories and Research Centre in Metropolitan Toronto located on the south side of Highway 401 near Islington Avenue. The original building was constructed in 1960; an addition, costing $11 million, was completed in 1974 to provide needed space for a steadily increasing work load. The complex also houses the research laboratory of the Pollution Control Branch and the Limnology and Toxicity Section of the Water Resources Branch.

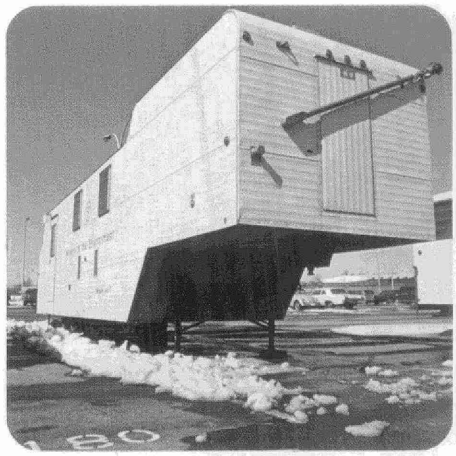
As a result of expansion, the branch operates one of the largest and best-equipped environmental analytical laboratories in Canada. This is a far cry from decidedly humble beginnings in 1957 when the entire lab facilities of the newly-formed Ontario Water Resources Commission consisted literally of an old tin shack on Richmond Street in downtown Toronto.

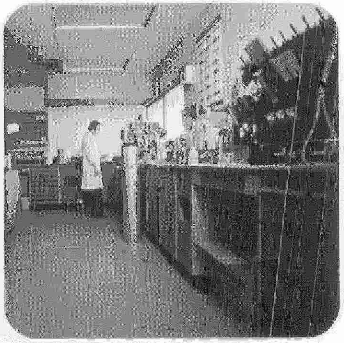
In addition to the central laboratory complex, the Ministry maintains lab facilities in the Queen's Park area of Toronto as well as regional labs in London, Kingston, Sudbury and Thunder Bay. Several mobile vehicles are also used to carry out on-site measurements for various pollutants. On water, similar work is done with a specially designed marine laboratory aboard The Guardian I.

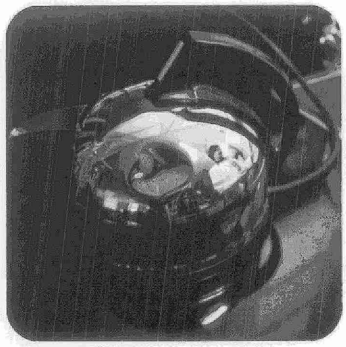
The technical staff of the laboratory branch totals over 200 scientists and support personnel. The regional labs plus the phytotoxicology, biology and research groups employ another 50 scientists and technicians.

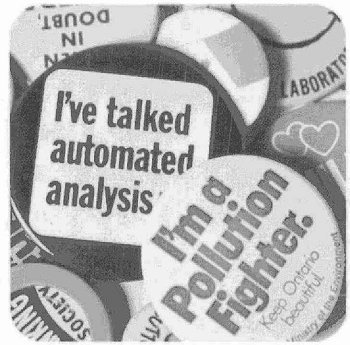
This sizeable commitment of human resources by the Ministry to analytical and research operations is an indication of the important role the scientist plays in diagnosing the health of the environment and providing the data upon which corrective measures can be taken.

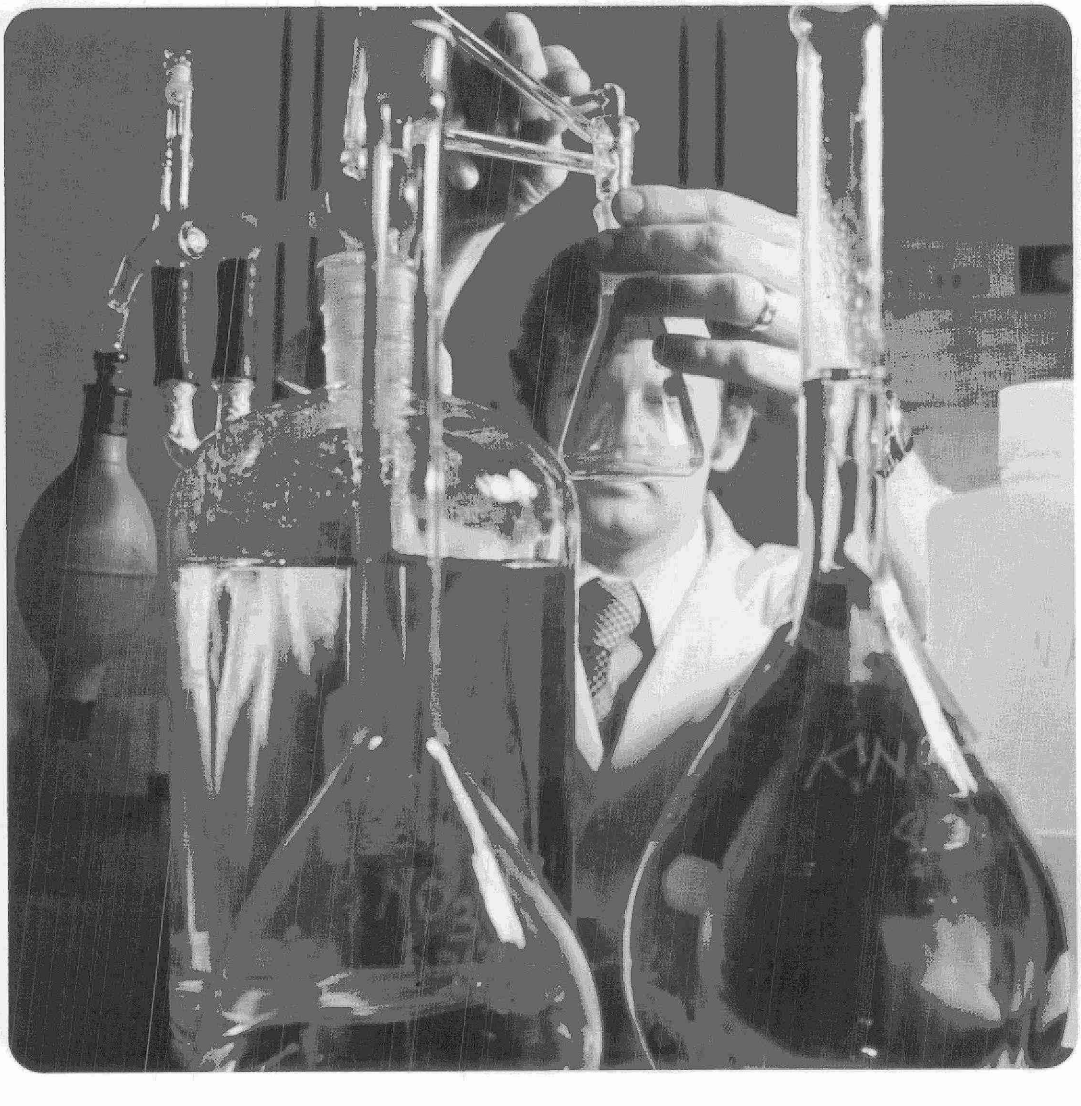
With its facilities and staff, the Laboratory Services Branch is well equipped to undertake the million-odd environmental tests required of it each year.

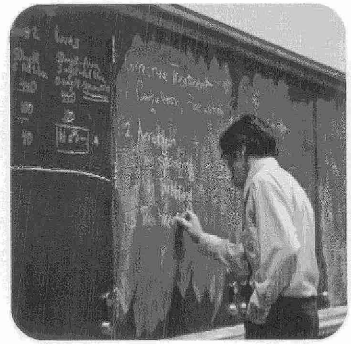


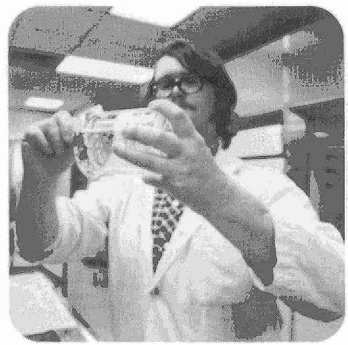





I've talked automated analysis
I'm a Pollution Fighter.
Keep Ontario beautiful



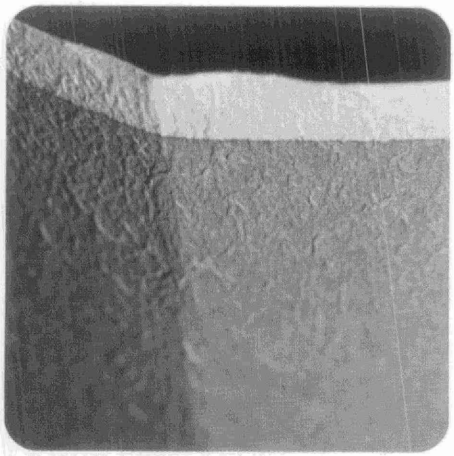




No Shortage of Materials

Some workaday samples for environmental analysis: dozens of bottles of drinking water, a pickled fish, some fruit and vegetables, a leaf from a green ash tree damaged by boron, and a close-up view (below) of a piece of filter paper covered with dust as the result of air having been drawn through it.

The fish has been kept in his preserved state for approximately the past 50 years. He was brought out of storage to be analyzed once again during a recent mercury study program. His preservative is formaldehyde. If the fish had been caught a decade or so earlier, however, he could have been pickled in any one of a variety of agents, including whiskey.



There is definitely no lack of work for an environmental laboratory. Daily, several hundred bits and pieces of Ontario's environment come through its doors to be analyzed for a wide variety of known and unknown pollutants.

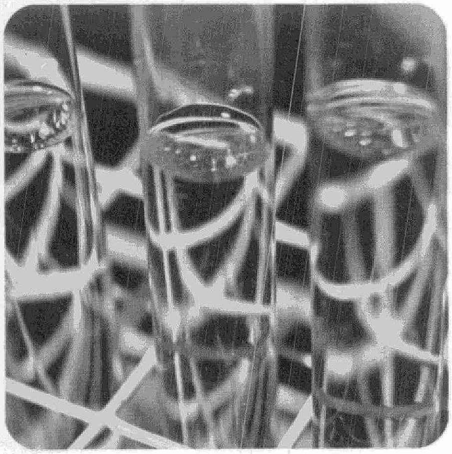
The nature of these samples is a direct reflection of the fact that air and water are the two great receivers and transporters of pollution from both natural and man-made sources.

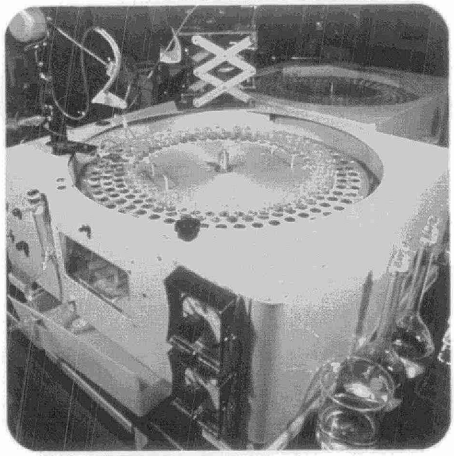
Hundreds of bottles of water, for example, are brought to the lab's Toronto facilities every day as part of routine testing and spot-check programs on the province's lakes, streams and drinking supplies. Also received are samples of municipal and industrial waste materials, water vegetation, bottom sediment, plus specimens of the aquatic food chain from phytoplankton up to large game fish and fish-eating birds.

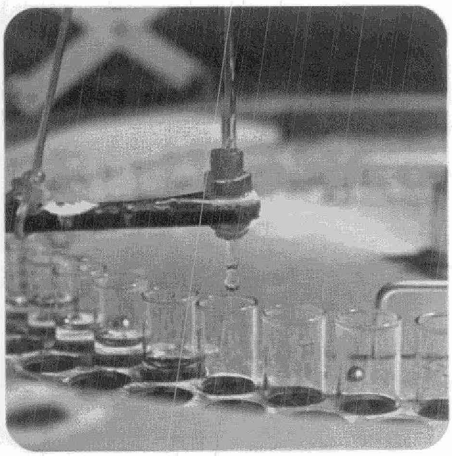
Air-related samples come from a similar variety of sources. They include plastic bags filled with ambient air as well as vegetation, soil, fuel, dust and stack emissions.

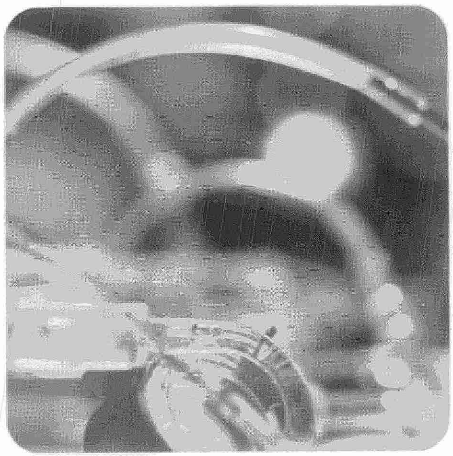
Inside the laboratory, the samples go many separate ways to the numerous special units and individual laboratories that, for organizational purposes, have been grouped into five main sections: Water Quality, Air Quality, Organic Trace Contaminants, Inorganic Trace Contaminants, and Microbiology.

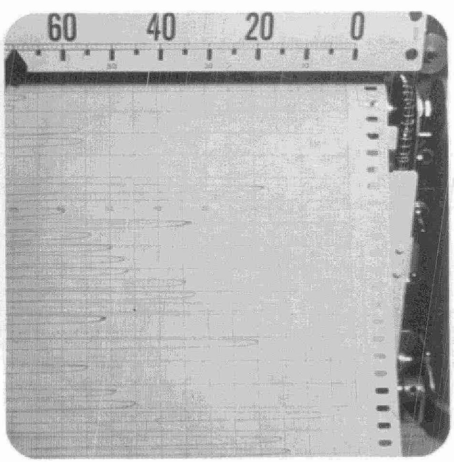
Here, in these many testing areas, the complex job of environmental analysis takes place.

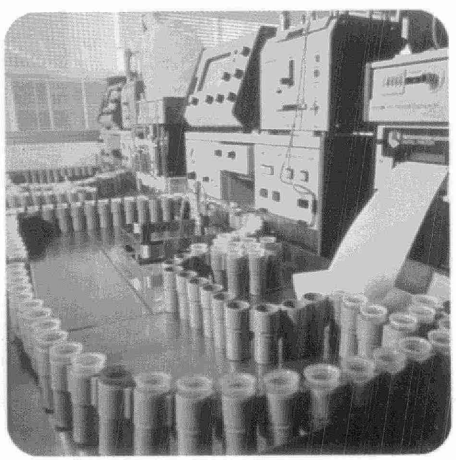









60
40
20
0

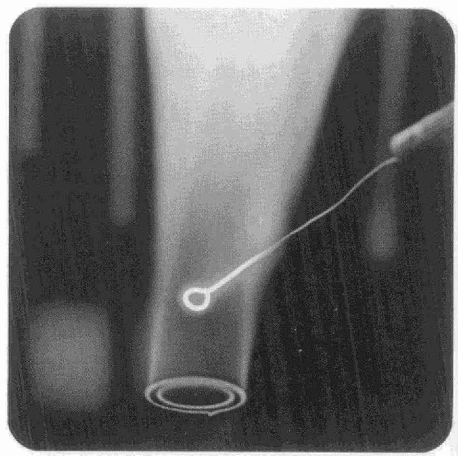


An Ongoing Process

The day-to-day work of environmental scientists and technicians is a constant round of searching out and then isolating, identifying and measuring most of Nature's elements and thousands of both natural and man-made organic and inorganic compounds present in air, water, soil, plants and animal life. It is a complex job and is not getting any easier in face of man's accelerating technological development.

A decade or so ago, the impact of pollution upon the environment was less understood and pollution control requirements were consequently less demanding. The range of analysis required for both air and water was relatively narrow and only a few parameters were deemed necessary to characterize their respective qualities. Examination was primarily restricted to obvious signs of trouble such as suspended solids, oils and dyes in water, and black smoke, dust and strong odors in the air.

Today, much of the visible pollution has been brought under control and our attention has shifted mainly to



more insidious and invisible forms—mercury, pesticides, vinyl chloride, asbestos fibres, to cite only a few.

Some of these substances, in fact, are now so widespread that environmental scientists must not only study actual air and water more thoroughly than before but also the life forms they support. Through their work scientists attempt to provide as much information as possible by which the overall condition of the environment can be assessed. They also undertake studies to check the efficiency of abatement measures and conduct experiments to see if they can successfully predict the behaviour of given contaminants in the natural environment.

Ways and Means

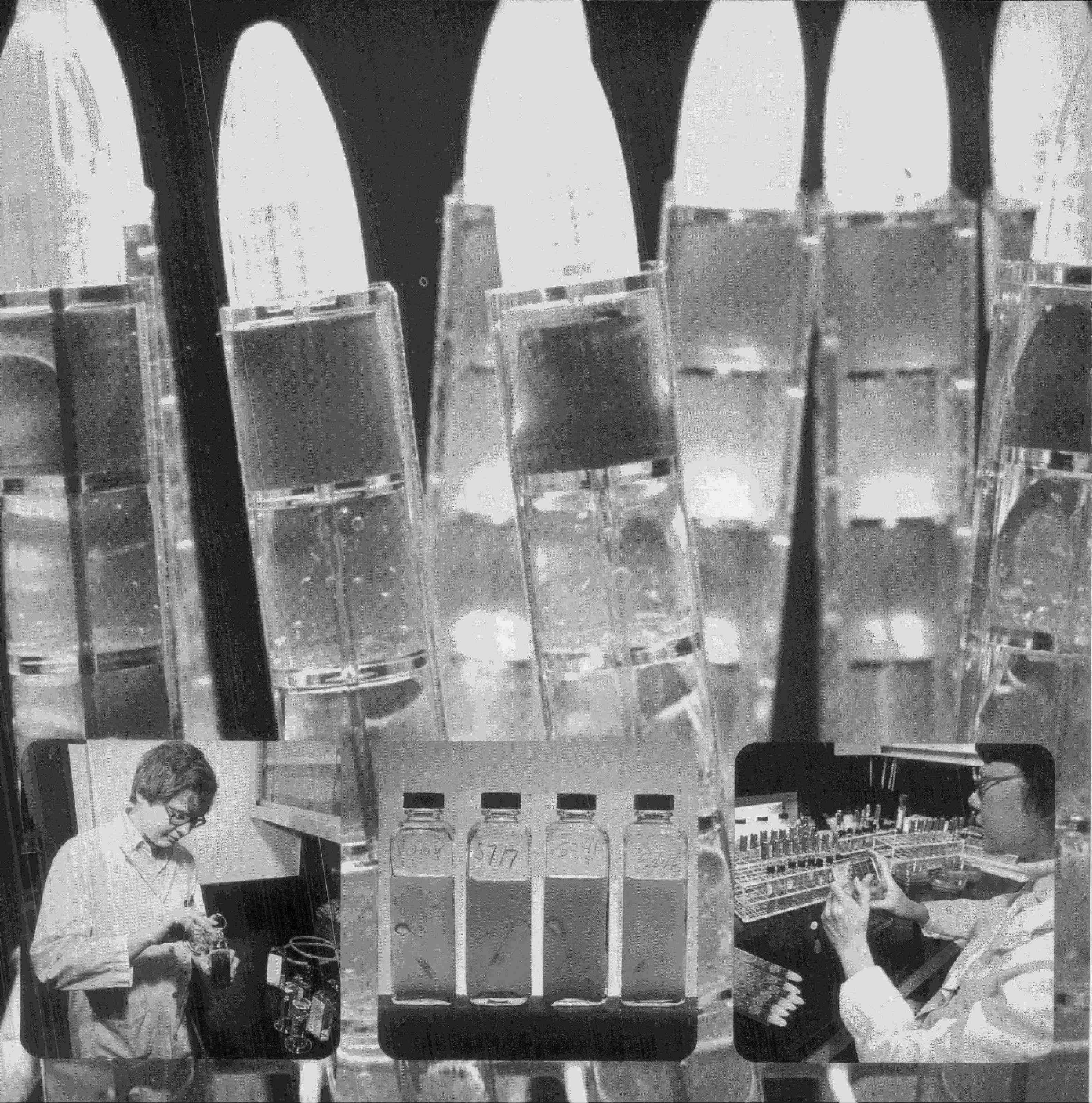
The procedures of the environmental laboratory are, by turns, both delicate and destructive, a mix of classical chemistry and new technology, and its work is being performed more quickly and accurately than ever before.

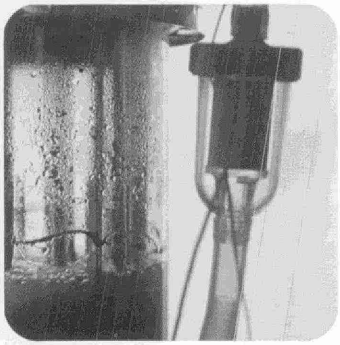
Automated analytical procedures coupled with computerized data processing, for example, have greatly simplified many routine laboratory tasks. Other developments have provided the analyst with new capabilities to isolate and identify trace quantities of some elements and compounds in ultra-minute concentrations of parts per billion and even parts per trillion.

The highest degree of automation has occurred in the area of water analysis where automatic analyzers are used for measuring a wide variety of pollutants in samples from lakes, rivers, surface and ground waters, drinking supplies, municipal sewage and industrial waste effluents.

Water is the most frequently lab-

Automated techniques are being used more and more for routine water testing.
The girl (bottom right) is testing water for its chemical oxygen demand.


5717
5241
5446



The fermenter (above) allows controlled laboratory studies to be made of interactions between micro-organisms and pollutants in simulated natural conditions.

Presence-absence bacteria testing begins (lower left) with the addition of a sample of water suspected of containing pollution-indicator bacteria to a broth that will support their growth.

Presence of such bacteria is shown by color changes and/or gas production as in bottles in 5068, 5717 and 5241; absence, by no change to contents as in bottle 5446.

Identification of actual bacteria present is made by isolating and injecting samples of each bacterium into a variety of media contained in compartmentalized tubes (full page). The media are formulated to detect individual biochemical and physiological characteristics. Each type of bacterium reacts differently and can be identified by the color changes it causes in the various media.

The membrane filtration test (below left and right on this page) reveals how many bacteria are present in a given water sample. Bacterial colonies are allowed to grow from single cells on a special filter placed in a nutrient medium. Coliform bacteria, which indicate the possible presence of contamination from human and animal wastes, are identified by their unique metallic greenish-gold color.

The number of bacteria present is a key measure of drinking water quality.

tested part of the environment because of the many uses to which it is put. Water is regularly analyzed for nutrients such as phosphorus, ammonia and nitrogen as well as for many other elements and compounds and also for chlorophyll concentrations (a key parameter for establishing the extent of lake deterioration), biochemical oxygen demand, chemical oxygen demand and bacteria.

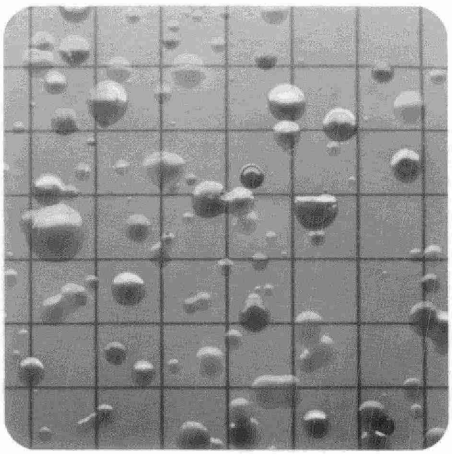
Getting the Bugs Out

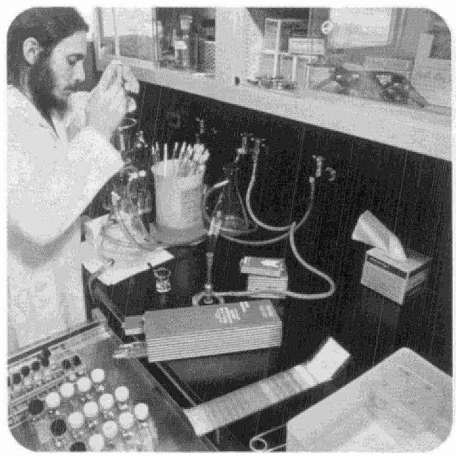
Bacteria play various roles in our lives. Many are beneficial; some are merely nuisances; others, unfortunately, are deadly.

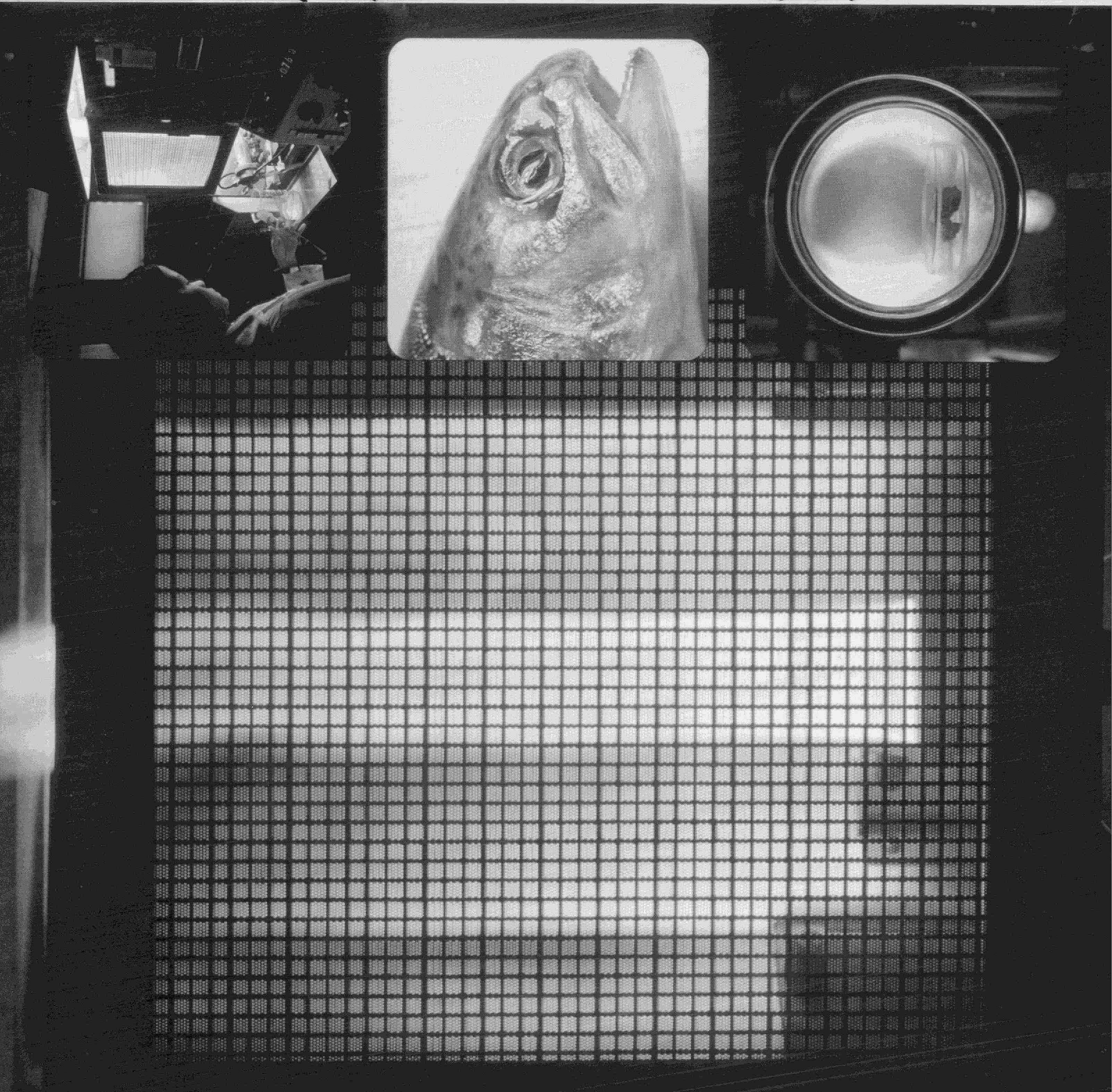
Helpful bacteria include those in plants which convert atmospheric nitrogen into usable nutrients. Nuisance varieties cause taste and odor problems and clog water distribution systems. Deadly types are directly responsible for such diseases as cholera and typhoid fever, and may indirectly include certain fresh water bacteria busily working away on waste mercury and certain other metals, converting them from their less dangerous inorganic states to toxic organic forms.

Bacteria constitute an important area of environmental study, and a careful watch of our drinking water is kept for those types capable of causing mischief and disease. Some are tolerable within certain limits; others are harmful by their very presence. To find and measure them, several procedures are used including membrane filtration (MF) and presence-absence tests (P-A).

MF testing of a given water sample reveals how many bacteria are present; P-A testing determines the presence or absence of specific bacteria types. These tests provide a composite picture of the bacteriological quality of water.







Seeking the Elements

It certainly cannot be said that Nature's elements do not get around much any more. On the contrary, an unforeseen by-product of man's continuing resourcefulness has been the more widespread distribution of many elements throughout the environment.

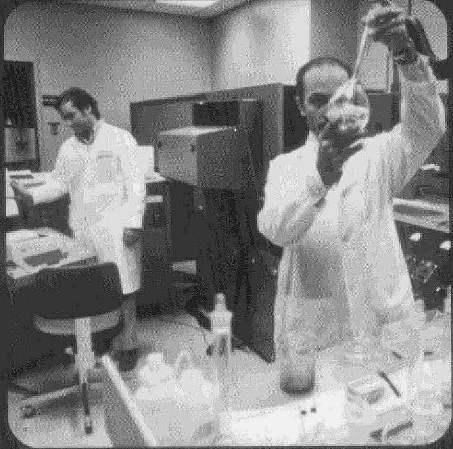
Ministry surveys have turned up many metals including lead, cadmium, nickel and vanadium in suspended dust particles taken from the ambient air of various centres throughout Ontario. These same four metals have also been found in elevated concentrations in the roses and carrots of some urban back gardens located near metal processing plants.

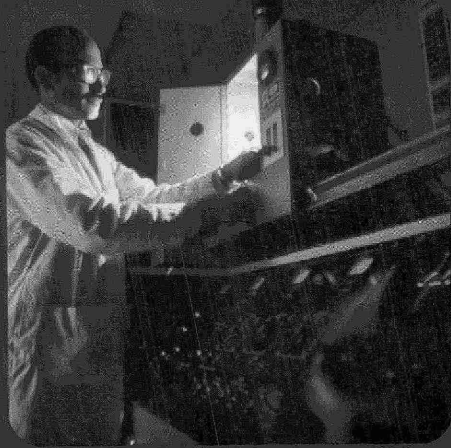
Heavy metals such as mercury, cadmium and lead are of particular concern as they are highly toxic to many life forms at extremely low levels. Their introduction into the environment from industrial or domestic discharges or as a result of such natural events as erosion can severely affect air and water quality. These metals in water, for example, can become part of man's food supply. Absorbed first by micro-organisms, they are passed up the food chain from one mouth to another, sometimes becoming thousands of times more concentrated along the way by the process of biological magnification.

The tools used for tracking down and measuring pollutants range from the familiar optical microscope to instruments with such strange-sounding names as atomic absorption spectrophotometer, anodic stripping voltammeter, and emission spectrograph. Some of them are particularly interesting in their operation.

The big flame is part of an atomic absorption spectrophotometer (top right). In this instance, a sample of bottom sediment is being analyzed for vanadium.

The rainbow trout is about to undergo testing for its heavy metal content while a geranium leaf (bottom right) is being reduced to an ash in an oxygen plasma. Many environmental samples are so treated to remove organic matter before analysis for metals.





00.1

The screen (opposite) lights up photographic plates obtained after testing a water sample with the emission spectrograph. The positions of the spectral lines reveal what metals are present.

Bottles (above) contain further samples to be tested. Running of the "emission spec" (above left) is a highly charged operation; an electrical spark provides the energy by which the elements in an environmental sample are made to reveal themselves.

What's in a Flame?

Atomic absorption spectrophotometers are the simplest and most widely used pieces of equipment for determining trace metal concentrations. Their operation is based upon the ability of individual elements in the atomic state to absorb light energy of specific wavelengths. Some types operate with a high temperature flame, others do not; the flame as illustrated here is but one mechanism for transforming the metal being tested from its normal ionic state to the atomic state.

Operation is one of simple routine. The sample, dissolved previously in an acid solution, is fed into the flame. At the same time, a cathode tube emits light energy at a wavelength specific to the metal being determined. Part of this light energy is absorbed by the metal atoms present in the flame. The concentration of the metal is directly proportional to the amount of the light absorbed and is automatically calculated. Up to 60 metals can be analyzed in this manner.

On the Right Wavelength

The atomic absorption spectrophotometer is normally used to analyze a sample for one element at a time. The emission spectrograph, although not as sensitive, is used to seek out and measure almost all of the elements in the sample at the same time. It also does the job in a very different way as indicated by the respective names of the two pieces of equipment. While the atomic absorption spectrophotometer measures absorbed light, the emission spectrograph measures emitted light.

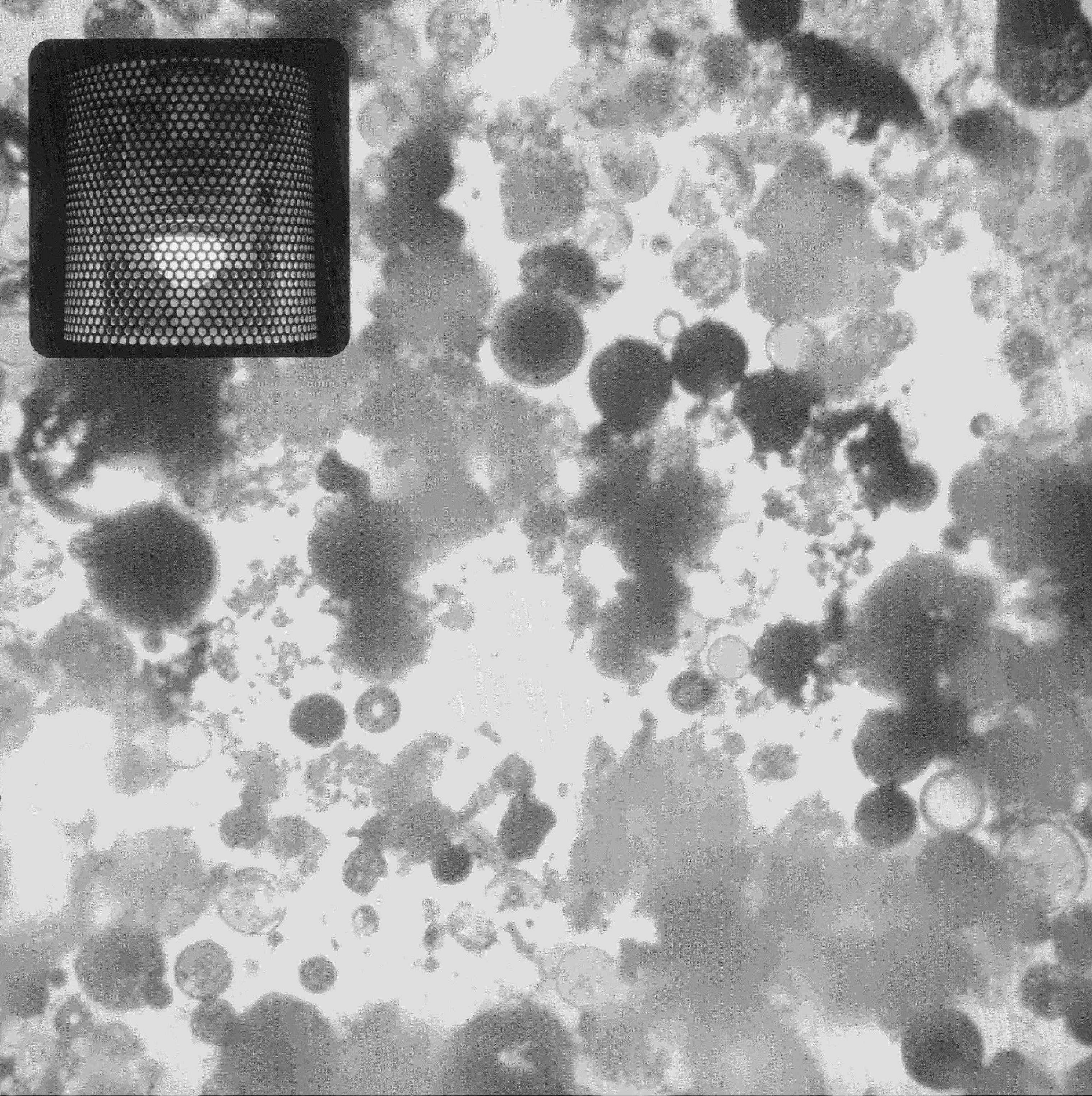
The procedure is quite straightforward. The sample, in either solid or liquid form, is placed between two graphite electrodes across which an electrical spark is generated. The energy produced excites the elements in the sample, causing them to emit energy at their own specific wavelengths.

It is this simultaneous emission of energy by each element that unmasks the sample's composition. Captured on a photographic plate, the energy emitted shows up as a series of spectral lines located at positions specific to each element. A look at the plate magnified onto a viewing screen reveals what elements are contained in the sample. The concentrations of the elements present can also be determined; they are directly proportional to the intensity of the spectral lines.

The emission spectrograph is a highly sophisticated analytical tool. It is regularly used for detecting and measuring approximately 70 of the elements although it can be adapted for determining nearly all of them.

Seeing Is Believing

Microscopes allow man to "see" inner worlds to literally unimaginable depths, and they play a major role in the identification of minerals, compounds and a



Fly ash from a power generating station shows many shapes and colors (left) when magnified 150 times with an automatic polarizing photomicroscope.

A high temperature induction furnace (inset left) is used to determine the carbon content of suspended dust particles taken from the air.

The colorful little flasks (below) contain water samples being tested for boron. The intensity of the red color is related to the amount of boron present. Actual concentrations are obtained using a spectrophotometer. Boron is an essential trace element for plant growth but it is toxic to both plants and animals at high concentrations.

The scientist (bottom right) is looking at the hidden inner world of an environmental sample through a transmission electron microscope.

diversity of other materials.

In the air pollution area, optical microscopes are used to identify pollutants such as dust, soot, vegetable debris and various fibres according to their morphological characteristics. These materials plus many other substances are routinely submitted for examination, sometimes after having been brought to the attention of the Ministry by members of the public.

Such "complaints" may help to pinpoint an unknown source of pollution and often aid in establishing evidence against a known one. In resulting court actions, laboratory scientists often act as expert witnesses. The complaint samples can consist of a host of natural and man-made materials, ranging from potentially dangerous industrial emissions to relatively innocuous bee-droppings.

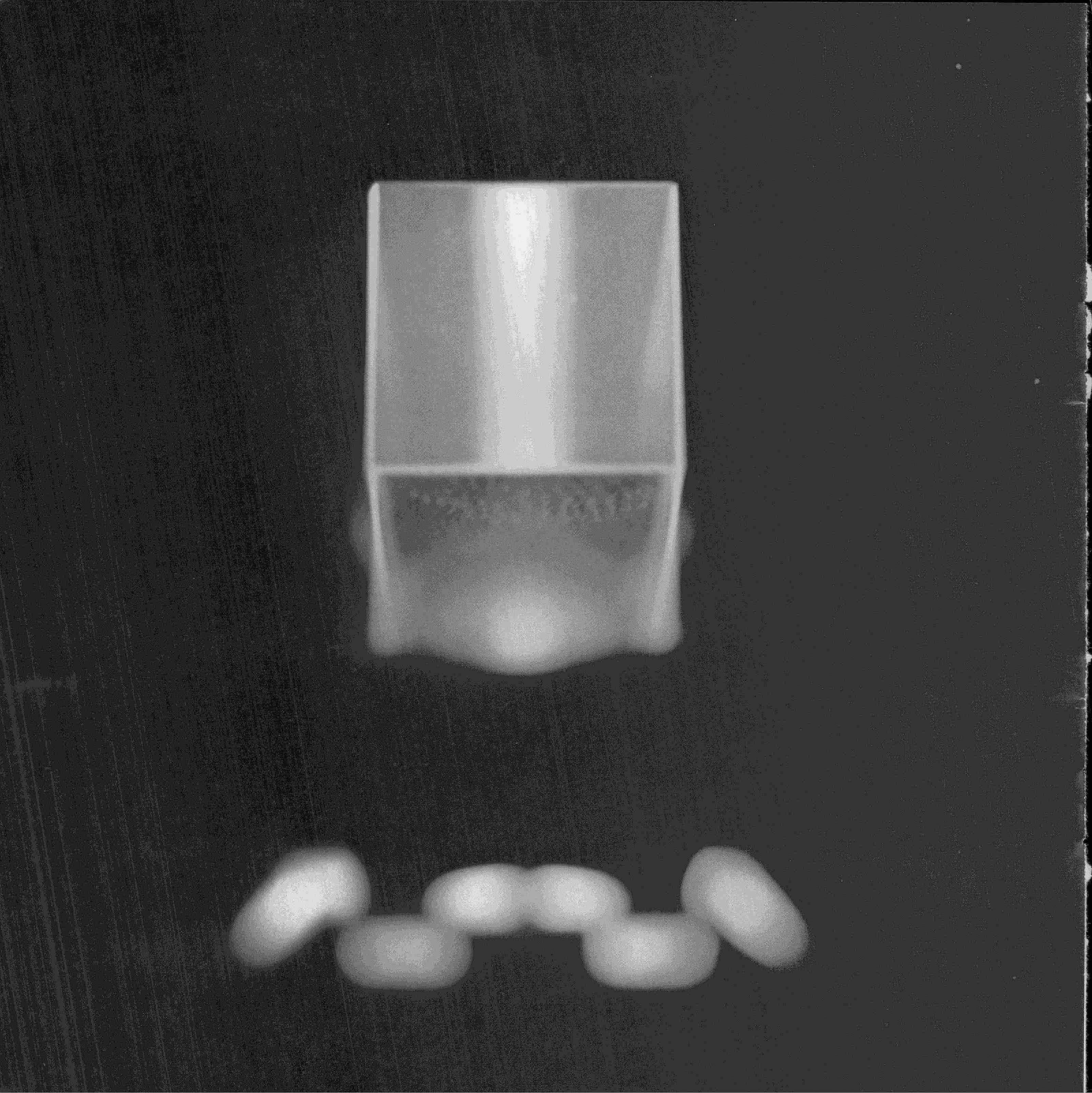
Electron microscopes take matters to a far more intensive level into the realm of many thousand times magnification.

The transmission electron microscope is similar in its operation to an optical microscope. Instead of operating with visible light and glass lenses, however, it utilizes the wave and particle nature of electrons together with electromagnetic lenses to form an image. This image can be focussed onto a fluorescent screen for direct observation or onto a photographic plate for future study.

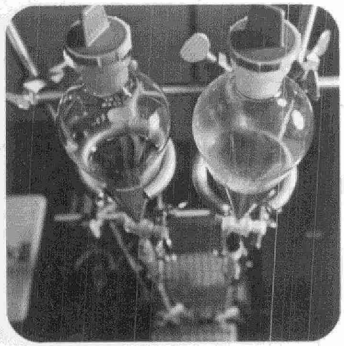
The extremely short wavelength of the electron beam produces the high resolution necessary to identify viruses and very small transparent particles such as asbestos. The electron diffraction capability of the microscope also makes it possible to identify compounds in material being examined.

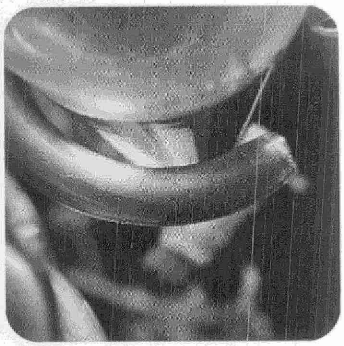
The scanning electron microscope operates somewhat differently. The surface of a specimen is scanned by an electron beam; those reflected are collected by a detector and, after suitable amplification, are made to form an image of the scanned surface on the screen of a cathode-ray tube.

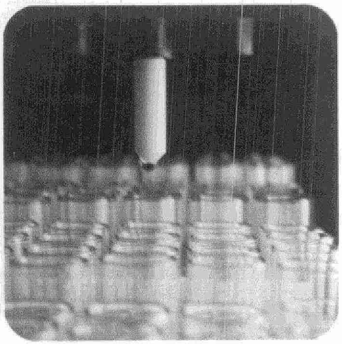
This microscope has the advantage of depth of focus and the ability to display the finest topographical details of air dust particles, sediments, sludges and vegetation. With the energy and wavelength dispersive spectrometer attached to the microscope, the elemental composition of a particle can be quickly determined.



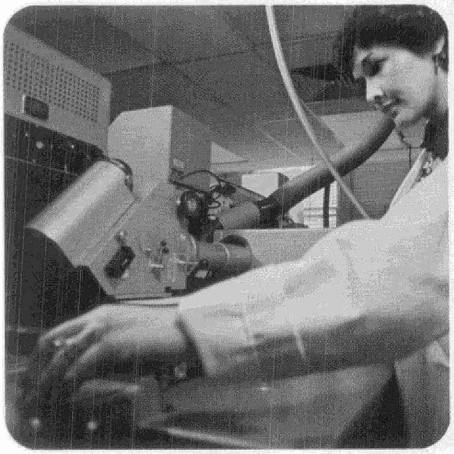
The quartz cell of a spectrophotofluorometer (left) provides a colorful display during operation to determine the concentration of benzo(a)pyrene it contains.
The column chromatograph (below sequence) is one of several procedures used to separate compounds from one another in an environmental sample prior to analysis with such an apparatus as the spectrophotofluorometer.
The technician (right) is operating a thin-layer scanning spectrofluorometer, another analytical tool.







The Problem Compounded



While the elements themselves are limited in number, their compounds are most certainly not as man continues to manufacture over a thousand new ones every year. And herein lies an environmental tale of great complexity and concern.

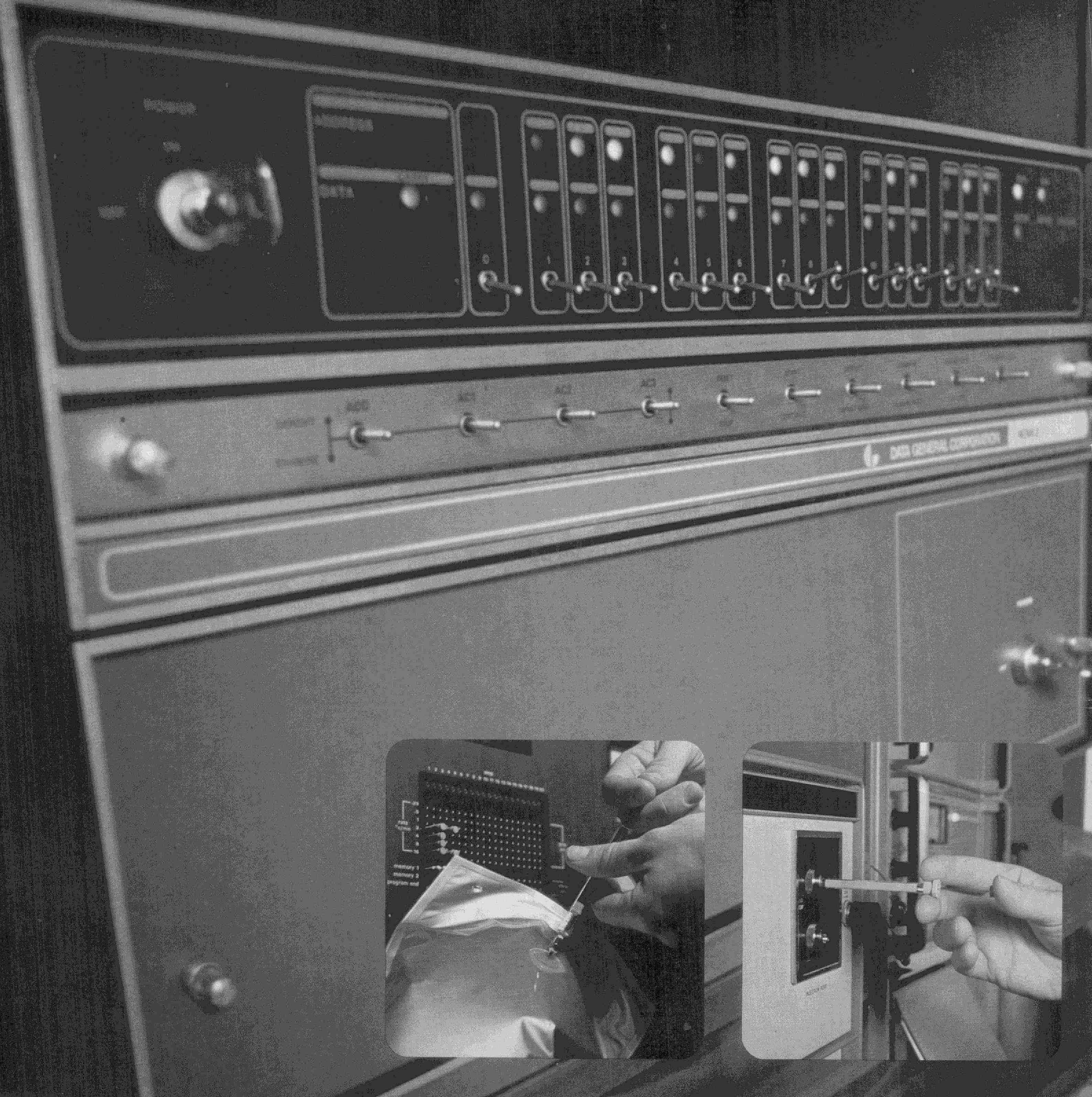
Compounds fall into two basic categories—organic and inorganic—although the boundary between them is somewhat blurred. Such organic-sounding compounds as carbon monoxide and hydrogen cyanide, for example, are classified as inorganic while methyl mercury and similar metal compounds are in a special class dubbed organometallics.

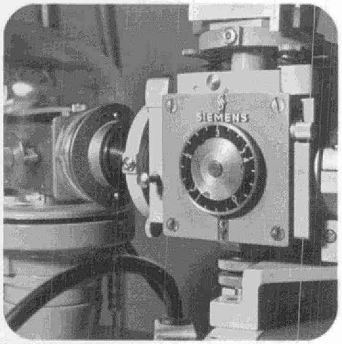
The types of compounds vary considerably as do the environmental problems they respectively pose. High on the investigative priority list are some very troublesome substances including pesticides, asbestos fibres, and such particularly esoteric organic compounds as vinyl chloride, polynuclear aromatic hydrocarbons and polychlorinated biphenyls (PCB's).

Many of these compounds are suspected of being cancer-causing agents, and much remains to be learned about them and their interactions within the environment. Complicating their detection is the fact that many of them are remarkably alike in structure and behaviour. However, help has been provided in the form of some highly sophisticated equipment by which they can be isolated, identified and measured. Especially effective are the spectrophotofluorometer and the gas chromatograph/mass spectrometer/computer system.

When Blue Becomes Green

For most of us, the workings of analytical instruments are beyond comprehension but there are the occasional few which are truly unique and relatively easy to understand. A case in point is the spectrophotofluorometer.


DATA
AC0
AC1
AC2
AC3
DATA GENERAL CORPORATION
memory 1
memory 2
program end



The X-Ray diffraction unit (above) is another important apparatus used to identify compounds.

The computer (left) is playing an increasingly important role in environmental analysis and is an indispensable part of the compound identification process undertaken with the gas chromatograph/mass spectrograph (far right).

Against the background of the Ministry's "mass-spec" computer (opposite), a portion of air is being withdrawn from a sample bag (left) and injected into a gas chromatograph (right) for analysis.

Its operation is deceptively simple as illustrated in part by the photograph of its quartz cell.

The cell in this instance contains in solution an amount of benzo(a)pyrene, a suspected cancer-causing hydrocarbon extracted from an air dust sample. Into it is beamed a shaft of blue light; out of it comes a greenish-yellow light. The fluorescence or emitted light is due to the presence of the benzo(a)pyrene. A measurement of its intensity reveals the amount of benzo(a)pyrene in the sample.

Pollution Fingerprinting

Measuring the concentrations of known compounds is no longer very difficult for an environmental lab. Identifying compounds of similar structures or those in complex mixtures, however, can still pose problems. Enter the gas chromatograph/mass spectrometer, an example of two analytical tools brought together to function as one.

Various chromatographic techniques are used to separate individual compounds based on the operating principle that compounds pass through columns of special materials at different rates. The gas chromatograph in particular is the lab's main workhorse in this area; it is also used for purposes of identification and measurement.

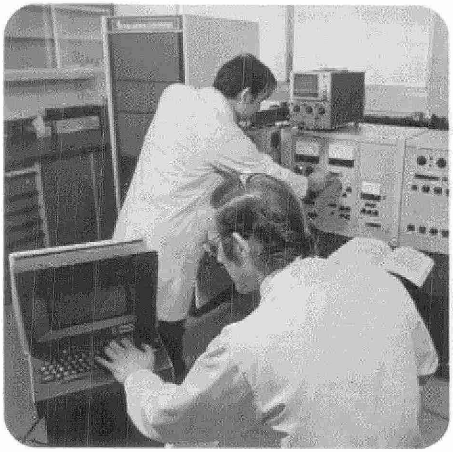
The mass spectrometer is primarily an identification tool of high sensitivity. Brought together, the gas chromatograph and the "mass-spec" constitute the environmental scientist's ultimate weapon for isolating and identifying organic pollutants. Put very simply, the process consists of the following three stages:

(1) injection of a sample into the gas chromatograph to separate its constituent compounds;

(2) transfer of one compound at a time into the mass spectrometer to be blasted apart into ionized fragments and then separated in an electrical and magnetic field to yield its mass spectrum, a feature of a compound as unique as a human fingerprint;

(3) comparison of the spectrum obtained against reference spectra on record with the aid of a computer for rapid identification from among the many thousands of possibilities that exist.

Quite a process. The work of the environmental scientist has certainly come a long way in a very few years.



Toward Solutions

The work of environmental analysis is a never-ending process for the Laboratory Services Branch. In spite of the advances that have been made, environmental scientists are only at the threshold of really understanding some of the infinite number of interactions taking place within the complex web of the environment.

Each day, however, brings new insights and solutions as the branch continues its very active role within Ontario's environmental protection program. Like the rest of the Environment Ministry, the branch operates with a twofold goal in mind: to eliminate existing environmental problems; and to prevent as many new ones as it can from developing in future. The work ahead may be endless, but it certainly is not impossible.

96936000009520

Environment
Ontario